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Dear Dr. Lederberg:

Thank you for your letter of August 10.

I see that we have some terminology difficulties, and I must confess that they are equally great on my side, since I do not seem to have a clear idea of what the terms "self-sufficient," "indifferent," and "information," that you are using, mean. Doubtless, they are explained in the other parts of your paper, but since I only saw a few pages of it, I am confused.

In view of this, it would seem to be best if I described precisely what my remarks meant. In other words, I will describe in detail to what sort of construction I am referring.

To be more exact, I have made several constructions which differ in the models of "parts," "organisms," and the spacial relationships of these to each other, that they assume. During the last few years, I have come to believe that one particular procedure is logically more economical than the others, and I will, therefore, use this in what follows.

Under this dispensation, then, I mean by the environment M, a quadratic lattice, as shown in the attached figure* and thought to be infinitely extended in both dimensions, and in both directions. The circles in that figure are the basic organs, the lines connecting them are connections over which impulses can travel. (Please ignore the area surrounded by a dashed line, shown in the figure, for this first part of the discussion.) All these basic organs are identical among each other. Every one has a finite number of states, say N -- in the construction that I used, the N is less than 30. The basic organ also has a definite scheme of behavior. By this, I mean a complete set of rules which specify that if an organ is in a state i (= 1, ..., N), and if its 4 neighbors (enumerated, say, in the order north, east, south and west) are in the states j,k,l,m, respectively, then after the lapse of one time unit, the first mentioned organ will go over into a specified state $i^1 = F\ (j,k.l,m)$. (Of course, the same happens to its neighbors, with respect to their own neighbors, and generally to all basic organs in the lattice.) Thus, the function F is a complete specification of behavior for the

*See last page

basic organ. I repeat, all basic organs have the same function F, i.e., the same behavior. In addition to this, one of the states, say the state $i = 1$, to be called the "rest state," has the property, that if an organ, as well as all its 4 neighbors, are in this state, then the first mentioned organ will be in this state a unit time later, too. (Of course, anyone of its neighbors may itself not be entirely surrounded by neighbors in the rest state. Therefore, this neighbor may not be in the rest state after a unit time, and therefore, the original organ may not be in the rest state after 2 units of time.) Note, that I am treating time as an integer, i.e., I am only considering moments of time $t = 1,2,3,\ldots$

The normal condition of M is one, in which all of its basic organs are in the rest state.

The connecting lines on which, as I said before, impulses are supposed to be traveling, have no further significance. I am only using them to indicate that each basic organ is immediately affected only by the 4 neighbors that I enumerated above, i.e., precisely by those to which it is directly connected by such lines.

An "organism" A is an area in M, like the one shown on the figure, surrounded by a dashed line, in which the states of the basic organs have been prescribed in some definite way -- i.e., in which they are not necessarily all in the rest state.

Coming to the theorem that I mentioned in my previous letter, the organisms A and A^1 are disjunct. The theorem is, that given any A, I can construct an A^1 such that if A^1 is left to itself for a sufficient length of time, there will appear in M (of course, at disjunct, and if desired, widely separated, locations in M) the original A^1 , plus an additional copy of A^1 (displaced), and a copy A (also possibly displaced).

Of course, the construction of A^1 will depend on what A is. To be more precise, most of A^1 is the same, no matter what A is; however, there will be a part of A^1 which is determined by the structure of A. This part of A^1, by the way, is not a copy A. It is, in a certain peculiar notation, a description of A -- i.e., it is related to A in somewhat the same way as the genetic material determining the structure of an organism as related to that organism.

I should add, that for all of this to be true, F has to be chosen in a certain particular way. However, this choice of F is quite independent of the choice of A (and A^1), i.e., it is the same for all possible A (and A^1).

I would appreciate if you would let me know whether this is sufficient clarification. I apologize if I have just re-described things that you had inferred already. I would be much obliged to you if you could tell me how this is related to your discussion and ideas.

Sincerely yours,

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John von Neumann

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